Ionizing Radiation Risk Notes

This presentation addresses the origin of radiophobia, risk and risk perception, the flawed LNT radiation dose-response model and its collective dose corollary, and a realistic dose-response model.

Slide 2 – hazard ranking activity slides
- discussion of risk rankings following completion of student ranking activity to better understand what drives risk perception

Slide 4 – risk maxims
- risk issues are emotional because they often have more to do with perception than reality
- response to risk issues generally driven by fear – important human trait that enhances survival, **but**
  - fear can distort reality and be crippling, leading to irrational decision-making
  - fear can lead to harmful government policies that affect almost everyone
  - fear has become a weapon used by elected officials, government regulators, and others to advance political, professional, and personal self-interests

Slide 6 – risk definition
- generally, no distinction made between theoretical risk and real risk when communicating risk matters to public
- potential consequences of theoretical risks generally modeled and heavily dependent on assumptions underlying risk model
- actual consequences of real risks can be measured

Slide 7 – emotional aspects of risk perception
- risk perception differences major obstacle to effective risk communication
- acceptability or unacceptability of risks often driven by emotions
- slide lists some factors that determine emotion-based acceptability or unacceptability of risks

Slide 9 – acceptance domains for voluntary and involuntary risks
- pictorial of commonly accepted voluntary and involuntary risk domains
- risk depicted in terms of fatalities per person-hour of exposure versus average annual benefit per person involved in dollars
- dashed line shows average mortality probability due to disease for U.S. population
- both voluntary and involuntary risk acceptance roughly proportional to 3rd power of associated benefit in this graphic

- "acceptable" probability of occurrence for involuntary risks approximately 1000 times lower than "acceptable" probability of occurrence for voluntary risks presenting same benefit
- illustrates significant influence that voluntary/involuntary nature of risks has on risk acceptability

Slide 10 – one-in-a-million chance of dying risk

- slide compares different risks by showing statistic associated with each item estimated to produce one-in-a-million chance of dying
- talking about statistical deaths can be misleading
  - actual deaths (real people) are fatalities clearly attributable to cause in question and tend to be immediate
  - statistical deaths are fatalities only seen in *mortality rate* increases for a population
  - saying that certain health hazard kills some number of people a year really means exposure to hazard shortens lives of some number of people (reflected by increase in overall mortality rate for a population); begs the question, by how much?

Slide 11 – loss of life expectancy

- third way of comparing risks is estimated loss of life expectancy – in this case from various industrial and health hazards

Slide 12 – risk/attitude correlation for involuntary risk of death

- natural death reference point – 1 death per person in 100 years (human lifetime)
- 1977 International Commission on Radiological Protection (ICRP) adopted risk-based approach to setting radiation protection standards
  - decided that valid method for judging risk acceptability of radiation work was by comparing to risks associated with other occupations recognized as having high safety standards; that is, occupations in which average annual mortality due to workplace hazards does not exceed 1 in 10,000 (10^{-4} probability)
  - objective was to establish probability of radiation-induced cancer risk for radiation workers no greater than 10^{-4}
  - higher assessed level of risk would necessitate expenditure of effort and resources to reduce risk to acceptance level

Slide 16 – radiation in perspective

- slide shows one way of visualizing relative differences in radiation exposure risks
- although providing necessary perspective, three problems with this graphic
  - comparing acute and annual chronic radiation exposures is comparing apples and oranges

- chronic dose is not cumulative (i.e., annual dose is meaningless)
- minimum annual radiation exposure linked to increased lifetime risk of cancer would be 7 times higher (i.e., 70,000 mrem), warranting a larger cube, for 0.08 mGy/hr (8 mrem/hr) high dose-rate threshold

- chronic radiation dose from living next to nuclear power plant for one year (if chronic dose was cumulative) equivalent to radiation dose from eating 10 bananas or 2 Brazil nuts

Slide 21 – LNT dose-response model

- model generated by linearly extrapolating very high dose-response data from atomic bomb survivors to zero dose, absent any low-dose data to support such an extrapolation
- although linear relationship may be observed between high-dose radiation exposures and cancer or genetic defect risk, such a relationship has not been observed for low-dose exposures
- low-dose exposures do not overwhelm body's adaptive protection systems

Slide 22 – LNT cancer risk assumptions

- slide shows unrealistic basis for ICRP radiological protection regulations
- non-cancer specific means all cancer forms assumed to have same radiological risk
- non-organ dose specific means all body organs assumed to have same dose susceptibility to damage
- radiation exposure (and therefore biological damage) assumed to be cumulative means body's adaptive protection mechanisms ignored
- collective dose risk means spreading small doses among large population increases probability of fatality
- note that occupational workers, who would receive higher "collective" dose than public, assumed to have lower fatal cancer risk than public; seems to indicate beneficial effect associated with higher dose – inconsistent with LNT model

Slide 23 – LNT cancer predictions graphic

- graphic shows LNT dose-response model lifetime cancer risk predictions for various low-dose-rate exposures
- notable observations
  - log scale for both axes, which span 7 orders of magnitude
  - low-dose-rate data covers up to 5 orders of magnitude below natural background dose-rate
  - exposures highlighted in graphic are chronic exposures, which are not cumulative, although similar plot would be generated for dose-rates in mSv/hr
- 42% normal lifetime cancer risk from American Cancer Society

- except for smoking and coal mining, all radiation exposures in graphic from external sources of low LET radiation (i.e., beta and gamma-ray radiation)
  - — tobacco contains radioactive polonium-210 (alpha particle emitter) which results in internal exposure of lungs to high LET radiation when tobacco smoke inhaled
  - — generally accepted that coal miners exposed to high LET radiation from high radon gas concentrations in coal mines; many coal miners also smokers
- except for smoking, all illustrated dose-rates less than that from natural background
- in reality, no meaningful lifetime cancer risk associated with any low LET radiation exposures shown in graphic

Slide 28 – collective dose fallacy

- collective dose defies Paracelsus – dose makes poison, which we know to be true because we consume arsenic in green leafy vegetables
- as absurd as this seems, government regulations imposed on naturally-occurring, but safe, levels of arsenic in drinking water mandate unwarranted reductions based on collective dose concept

Slide 31 – collective dose fallacy (cont.)

- table illustrates how collective dose predicts cancer fatalities for large populations exposed to only very small radiation doses
- each combination of dose and exposed population in table have same cancer fatality risk under collective dose concept
- application of collective dose concept to radiation safety leads to significant risk control implementation costs for no discernible risk reduction benefit

Slide 32 – refutation of collective dose concept

- ICRP avoided emphatically stating that collective dose should not be used for predicting cancer risk
- despite wording modifications, collective dose continues to be used to predict cancer risk of postulated accidental ionizing radiation releases

Slide 34 – refutation of collective dose concept (cont.)

- statement by A. David Rossin, past President of ANS, regarding deception underlying use of LNT and collective dose to support radiation safety regulations

Slide 35 – LNT model perpetuates radiation phobia

- cancer mortalities predicted by LNT dose-response model just nameless and faceless statistics that never manifest actual deaths; i.e., no predicted deaths ever verified to happen to real people

- LNT radiation-induced cancer mortality predictions merely means to frighten people

Slide 36 – Chary Rangacharyulu, professor of Physics and Engineering Physics at University of Saskatchewan in Canada, puts LNT dose-response model in proper perspective

Slide 38 – deception of LNT

- slide shows two of numerous articles published about LNT deception
- Edward Calabrese is American toxicologist and professor in Department of Environmental Health Sciences at University of Massachusetts Amherst
- also, Editor-in-Chief of scientific journal Dose-Response

Slide 39 – deception of LNT (cont.)

- unable to produce evidence that low dose/dose-rate ionizing radiation detrimental to human health and unwilling to recognize validity of data showing beneficial health effect, LNT supporters invoke precautionary principle as "conservative" approach to minimizing radiation risk
- use of LNT model is conservative only under assumption that biological effects of low dose radiation exposure always detrimental

Slide 40 – LNT deception consequences

- radiation phobia and LNT hypothesis birthed ALARA protocol

Slide 43 – unwarranted expenditures due to LNT deception

- flawed collective dose and LNT concepts led to unnecessary UMTRA site radiological remediation costs to avoid predicted radiation-induced cancer deaths over 100 years in nearby populations
- note that predicted radiation-induced cancer deaths are not real deaths, as no way to ascertain which, if any, nearby population cancer deaths over 100 years caused by exposure to low-level radiation from uranium mill tailings

Slide 44 – UMTRA Project data

- last column shows cost per (predicted) death prevented in millions of dollars for each UMTRA Project site
- at 12 of 20 UMTRA Project sites cost per (predicted) death prevented was more than $10 million, and for six sites cost per death prevented was more than one billion dollars
- for proper cost perspective, value of statistical life (VSL) in Western countries typically ranges from $1 million to $10 million
- one might conclude on basis of UMTRA project expenditures that VSL for prevention of radiation-induced cancer death judged to

be worth more than for prevention of cancer deaths due to other causes (presuming that cause of every cancer can be precisely discerned)
  - recall that ionizing radiation estimated to be cause of only 2% of all cancers

Slide 45 – lack of evidence to support LNT
- Rosalyn Yalow was American medical physicist and co-winner of 1977 Nobel Prize in Physiology or Medicine for development of radioimmunoassay technique
  - radioisotope tracing technique that allows measurement of tiny quantities of various biological substances in human blood as well as multitude of other aqueous fluids

Slide 49 – biological system response to radiation dose
- as shown previously, although DNA damage is linear function of radiation dose rate, DNA repair is highly nonlinear process
- at relatively low radiation dose rates adaptive protection mechanisms stimulated and cell “repair centers” correctly repair DNA breaks; “effective” damage therefore not linear function of dose
- only at relatively high radiation dose rates, when repair process begins to be overwhelmed, does dose-response behavior become linear function of dose

Slide 50 – realistic dose-response model
- depicted dose-response model accurately reflects non-linearity of biological response to low level radiation-induced cell damage that must be accounted for in regulating radiation risk
- unfortunately, government regulatory agencies continue to use flawed LNT model to regulate radiation exposures

Slide 51 – dual effect of low-dose ionizing radiation
- note that this graphic and previous graphic are same; direction of vertical axis risk just reversed
- hormesis dose-response model shows radiation-induced adaptive protection neutralizes radiation-induced DNA damage for acute doses up to 0.2 Gy
- hormesis dose-response model accurately portrays low-dose ionizing radiation risk

Slide 54 – Chernobyl emergency worker death from ARS
- graphic shows number of Chernobyl first responders who died relative to total number of first responders exposed in each dose range
- note that 2,000 mSv is threshold dose for ARS
- of 97 first responders who experienced ARS, 28 died from their exposure

- 22 first responders who recovered from ARS died from various causes in following 19 years
- one of most vivid examples of why linear extrapolation of high dose data to zero dose is fallacious

Slide 55 – Chernobyl radiation risk

- unfortunately, hysteria rules in absence of radiation data
  - even though radiation doses to other parts of Western and Eastern Europe never a significant threat, pregnant women advised to have abortions and cow milk was dumped

Slide 56 – Chernobyl radiation risk (cont.)

- despite evidence that LNT model is wrong, continues to be used to falsely predict dire consequences from low-dose radiation exposures

Slide 57 – Chernobyl radiation risk (cont.)

- despite differences between LNT mortality predictions and reality, LNT model continues to be used to assess consequences of hypothetical radiation releases and to justify unnecessary radiological protection regulations for low-dose radiation

Slide 58 – average annual radiation doses from natural and man-made sources graphic

- graphic shows global population whole-body exposures from end of World War II to year 2000 due to natural background radiation, nuclear medicine procedures, above-ground nuclear weapon testing, Chernobyl accident, and nuclear power operations and activities
- graphic shows radiation exposures of eastern European populations contaminated by Chernobyl radioactive fallout did not exceed exposures from natural background radiation
- note significant rise in medical radiation exposures that occurred in decades preceding Chernobyl accident

Slide 59 – 1957 Mayak weapons plant accident

- radioactive contamination accident resulting from chemical explosion in nuclear waste tank at Russian plutonium production and nuclear fuel reprocessing plant
- about 10,000 people potentially exposed to various radiation levels, with highest exposure being about 50 cSv
- graphic shows significantly reduced cancer mortality rates observed in 12 cSv and 50 cSv exposure cohorts in nearby villages compared to unexposed control cohort

Slide 61 – atom bomb survivor cancer mortality graphic

- epidemiology data shows decreased cancer mortality rate of atomic bomb survivors receiving radiation exposures <20 cSv compared to cancer mortality rates for control populations

Slide 62 – atom bomb survivor death rate graphic

- among about 100,000 A-bomb survivors registered at Nagasaki University School of Medicine, 290 male subjects exposed to <50 cGy showed significantly lower mortality than age-matched unexposed males

Slide 64 – home radon risk graphic

- graphic shows fallacy of home radon risk narrative
- Professor Bernie Cohen's initial five-year investigation of radon-induced lung cancer covered 1,601 counties, comprising about 90 percent of U.S. population
- research found that instead of increased cancer with increased presence of radon, cancer rate decreased significantly
- arbitrary EPA home radon remediation level of 4 pCi/L within hormetic region and actually beneficial to health
- 2021 Polish study confirmed relative number of lung cancers decreases with increasing radon concentrations up to about 200 Bq/m^3 (>5 pCi/L)
- radon levels up to 3700 Bq/m^3 observed in some dwellings in Ramsar, Iran with no evident ill-effect on inhabitants

Slide 65 – U.S. low-dose radiation studies graphic

- graphic generated with data from U.S. government low-dose radiation program shows beneficial effects of ionizing radiation doses up to 100 mSv (100 mGy)
- figure showing fallacy of LNT model removed from government website when low-dose radiation program cancelled